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# Using General Land Office Survey Records in Ecosystem Restoration Planning

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**PURPOSE:** This technical note describes how records from General Land Office (GLO) surveys can be used to help guide ecosystem restoration planning. The GLO surveys were conducted in the 18th and 19th centuries, prior to the extensive settlement of the United States frontier regions. Throughout much of the newly independent United States, the GLO surveyors recorded information on hydrography and terrain, as well as specific data on vegetation composition and structure. When these notes and measurements are transferred to a Geographic Information System (GIS) and overlain on modern maps and aerial photographs, the information can provide insight into both natural and man-made changes that have occurred to the physical and biological environment of a region. This historical information can aid ecologists in establishing a reference condition for a study area and can help to define opportunities for ecosystem restoration. That process is illustrated here using the GLO survey data for a unique wetland complex called Grassy Lake (Figure 1) in southwestern Arkansas.

Figure 1. Typical views of Grassy Lake in the Lower Little River Basin of southwestern Arkansas. The Grassy Lake ecosystem includes areas of lowland hardwood forest, cypress swamp, and open water.

**BACKGROUND:** Reference ecosystems are commonly used to guide restoration planning and evaluate restoration success. Reference conditions can be compared to existing conditions for a variety of ecosystem features, allowing ecologists to define opportunities for restoration, recognize situations where elements of the original system are no longer restorable, and determine where alternative restoration targets are more appropriate. Ecologists typically use the "least disturbed" or "minimally disturbed" conditions as a basis for comparison, and use the best remaining examples of a particular ecosystem type for points of reference. Ideally, that would include relatively pristine systems that show little or no direct human influence since the time of European settlement. Such places are rare, but the records of the original GLO surveys often supply information that can be used to describe that undisturbed condition.

The GLO surveys were initiated in 1785 to provide a basis for dividing and selling public lands within the newly established United States. Teams of surveyors were dispatched to various parts of the country to establish township, range, and section boundary lines according to a detailed set of guidelines (Bureau of Land Management 2009). The basic survey unit was the six-mile-square township, which was identified by a distance north or south of an east-west running Base Line, and east or west of the north-south running Meridian. Townships were subdivided into 36 one-square-mile sections (Figure 2) and again into quarter sections (Figure 3).

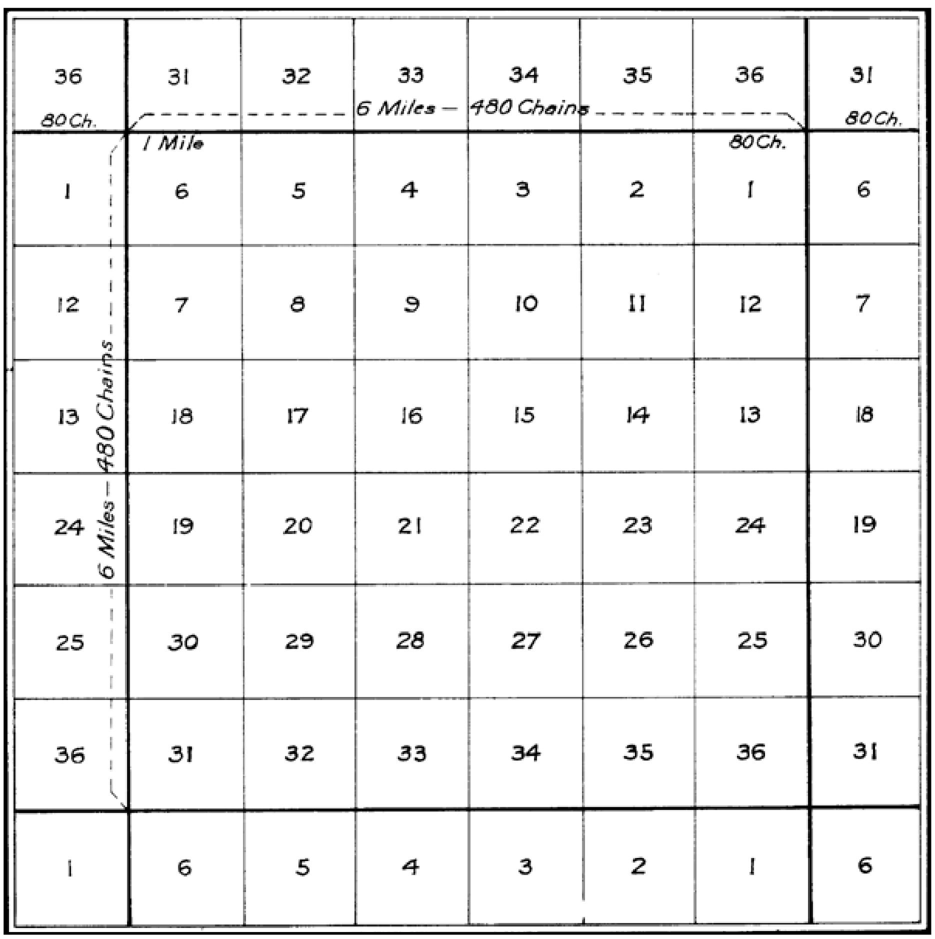


Figure 2. A schematic of a six-mile-square township, subdivided into 36 one-square-mile sections.

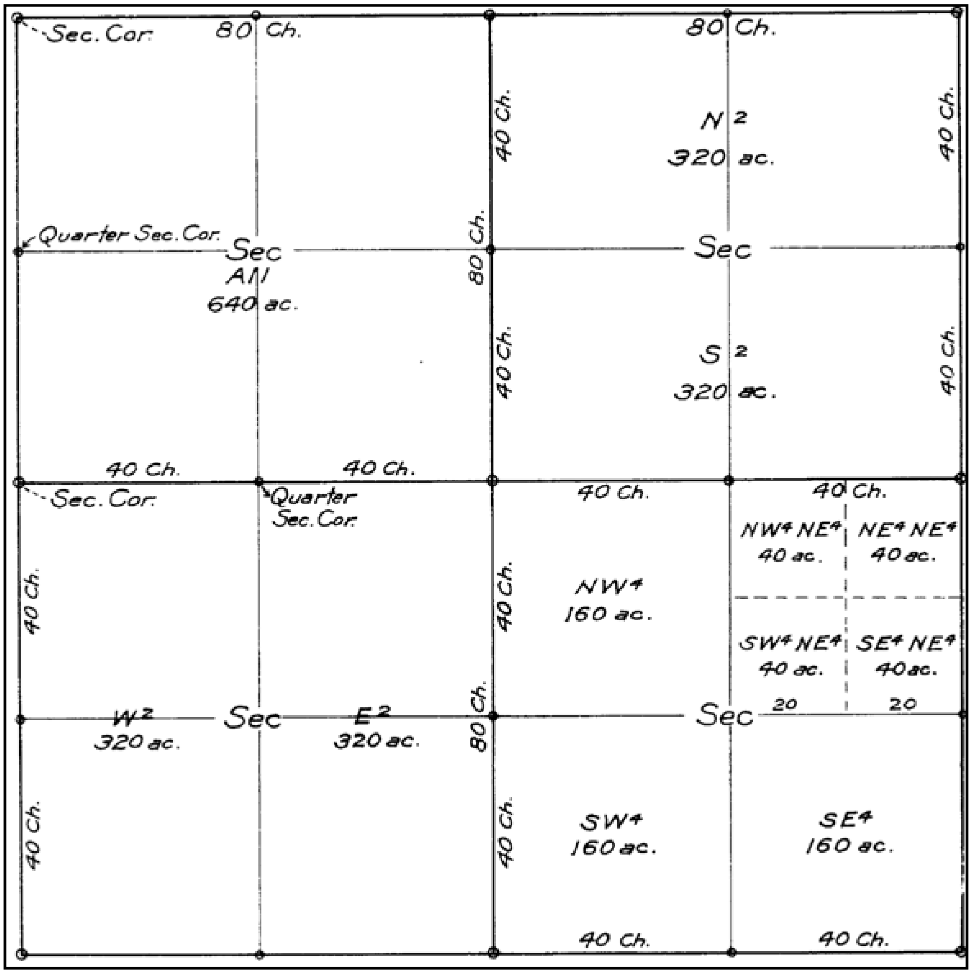


Figure 3. A schematic of 4 one-mile-square sections, illustrating the section corners and the quarter section corners. Linear measures were recorded in chains (80 per mile) and areas in acres (640 per section).

Specific guidance for how surveys were conducted and which data were recorded changed periodically (Stewart 1935), but the survey records always included two basic types of information: survey notes and plat maps. As the surveyors measured the section boundaries, they made detailed handwritten notes on the environmental features and landmarks they encountered and recorded their locations (Figure 4). They used these notes to create plat maps of the townships, which illustrate the location of major landscape features such as lakes and rivers (Figure 5).

The most detailed data in the survey notes concern forest composition and structure, including measurements of individual trees (Dodds et al. 1943). Surveyors recorded the species and diameter of two or more trees along the survey line between quarter section corners. More detailed data were collected for bearing trees (sometimes called witness trees) at each ½ mile and 1 mile interval; these intervals correspond to the quarter section and section corners identified in Figure 3. Bearing tree data included species and diameter, as well as distance and direction from the line. These data also were recorded for two bearing trees at each fractional corner; these were points where obstacles, such as water bodies, prohibited the surveyors from continuing along the survey line. At each mile or half-mile interval (depending on the prevailing guidance) the surveyors briefly characterized the surrounding landscape, including the topography, the predominant vegetation, the quality of the soil, and whether the area was fit for cultivation. If the line crossed a bottomland, the surveyors determined whether the bottomland was prone to flooding and estimated the flood depth.

The surveyors also recorded hydrographic information. They were instructed to describe all rivers, streams, creeks, and springs that intersected the survey lines and to note their direction of flow and width (Dodds et al. 1943). They were also instructed to note other water features, such as swamps, ponds, and lakes, and to indicate when the survey line entered or exited a river bottom or creek bottom. Navigable rivers were surveyed along their entire banklines, and large lakes were surveyed along their perimeters. Based on these surveys and on extrapolations between survey points, plat maps were created that depict the approximate size and location of all water bodies in each township (see Figure 5).

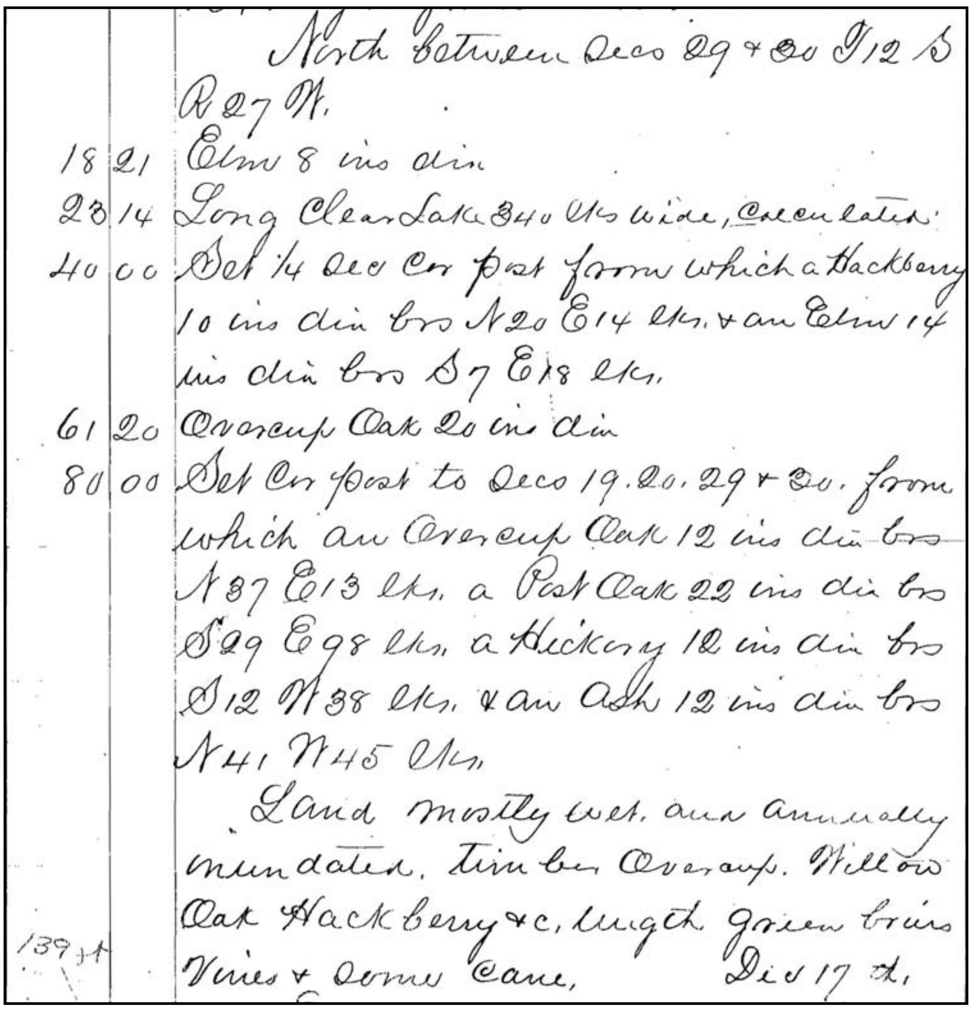
North between Secs 29 & 30 T12 S
R 27 W.
18 21 Elm 8 ins dia
23 14 Long Clear Lake 340 lks wide, circulates
40 00 Set 1/4 Sec Cor post from which a Hackberry
10 ins dia brs N 20 E 14 lks. & an Elm 14
ins dia brs S 7 E 18 lks.
61 20 Overcup Oak 20 ins dia
80 00 Set Cor post to Secs 19.20.29 & 30. from
which an Overcup Oak 12 ins dia brs
N 87 E 13 lks. a Post Oak 22 ins dia brs
S 29 E 98 lks. a Hickory 12 ins dia brs
S 12 W 38 lks. & an Ash 12 ins dia brs
N 41 W 45 lks.
Land mostly wet and annually
inundated. Timber Overcup. Willow
Oak Hackberry &c. Undgth green briars
139 H Vines & some Cane, Dec 17th.

Figure 4. The surveyor's handwritten notes for the line between sections 29 and 30 of Township 12 South (T12S) and Range 27 West (R27W), which encompasses Grassy Lake. This information was recorded on December 17th, 1834.

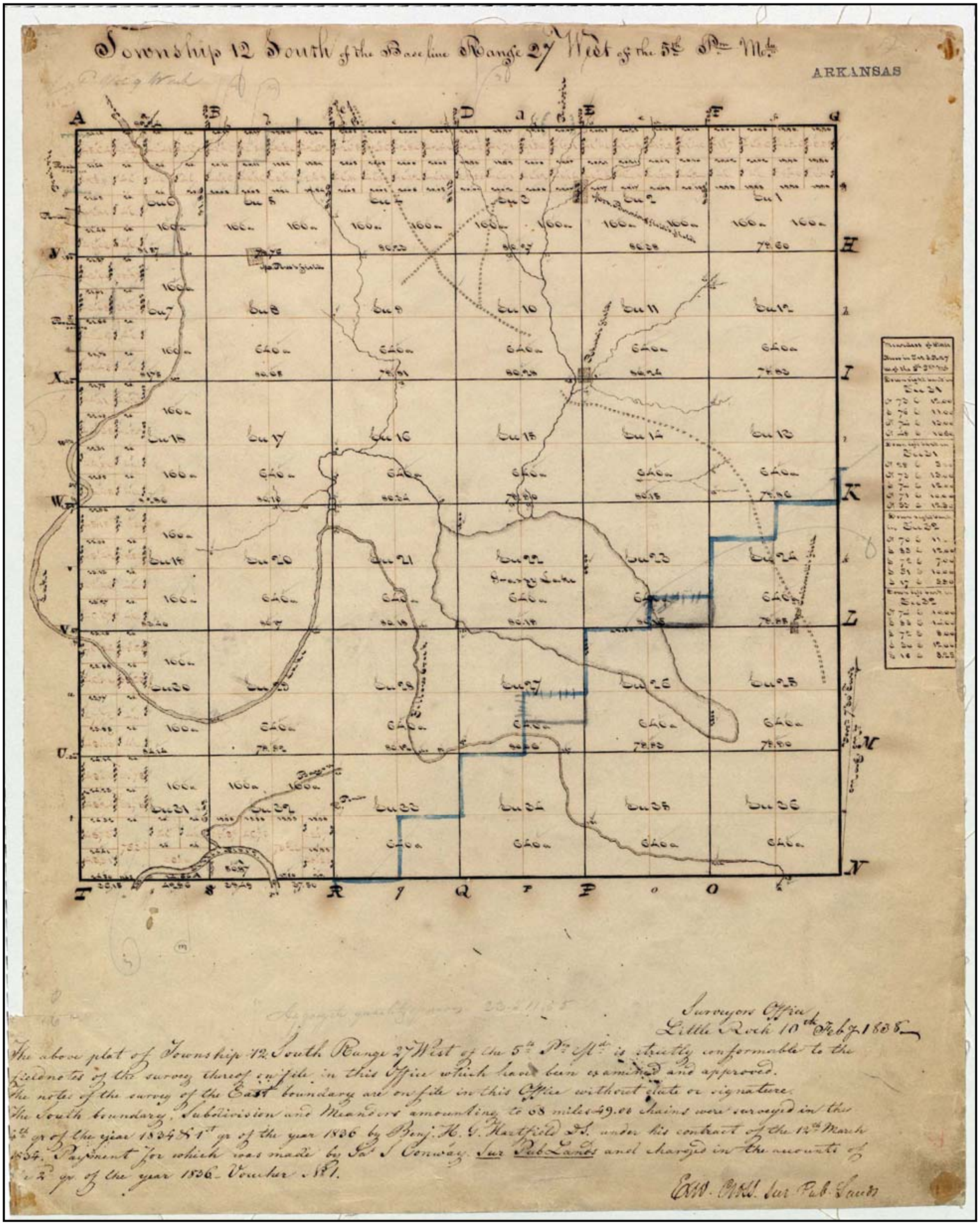


Figure 5. The plat map for T12S R27W showing the various landscape features the surveyors encountered, including Grassy Lake.

## CASE STUDY: GRASSY LAKE

**INTRODUCTION:** The Lower Little River Bottoms ecosystem is a complex of approximately 15,000 acres of lowland hardwood forest and an extensive bald cypress swamp known as Grassy Lake. Located in the alluvial valley of the Little River in southwestern Arkansas, just downstream from the U.S. Army Corps of Engineers (USACE) dam that impounds Millwood Lake, it is one of the largest contiguous tracts of diverse bottomland forest remaining in the Gulf Coastal Plain Region of the United States (Figure 6). It is particularly well-known as a traditional waterfowl hunting area (Figure 7), and private landowners have protected it for that purpose from the intensive forestry and agricultural activities that have altered the surrounding landscape.


Figure 6. Digital orthophotograph of the study area showing selected major physiographic and cultural features. Little River was impounded to form Millwood Lake, in the northwest corner of the image.

The dynamic flood patterns that influenced the area were dramatically changed in the mid-20th century when the federal government, through the USACE, built a series of dams specifically for flood control on the Red River and its tributaries, including streams in the Little River drainage basin. These structures, particularly Millwood Dam, effectively disconnected the floodplain ecosystem from the Little River in all but extreme flood events. At about the same time, private landowners began to substantially modify the adjacent uplands and major contributing local watersheds, changing the pattern of local runoff and increasing sediment inputs to the system. Although natural flooding was largely curtailed, the lands within the Lower Little River Bottoms, almost all of which are within private hunting clubs, were modified using levees, pumps, and drainage structures so that water could be detained or diverted into the lowland forests and Grassy Lake and managed for waterfowl hunting and fishing. These modifications substantially raised water levels within Grassy Lake, and altered natural flood patterns in most of the bottomland and swamp forests. After more than a half century, the effects of these man-made changes are evident in degraded hardwood stands, aquatic weed problems, and lack of cypress reproduction.

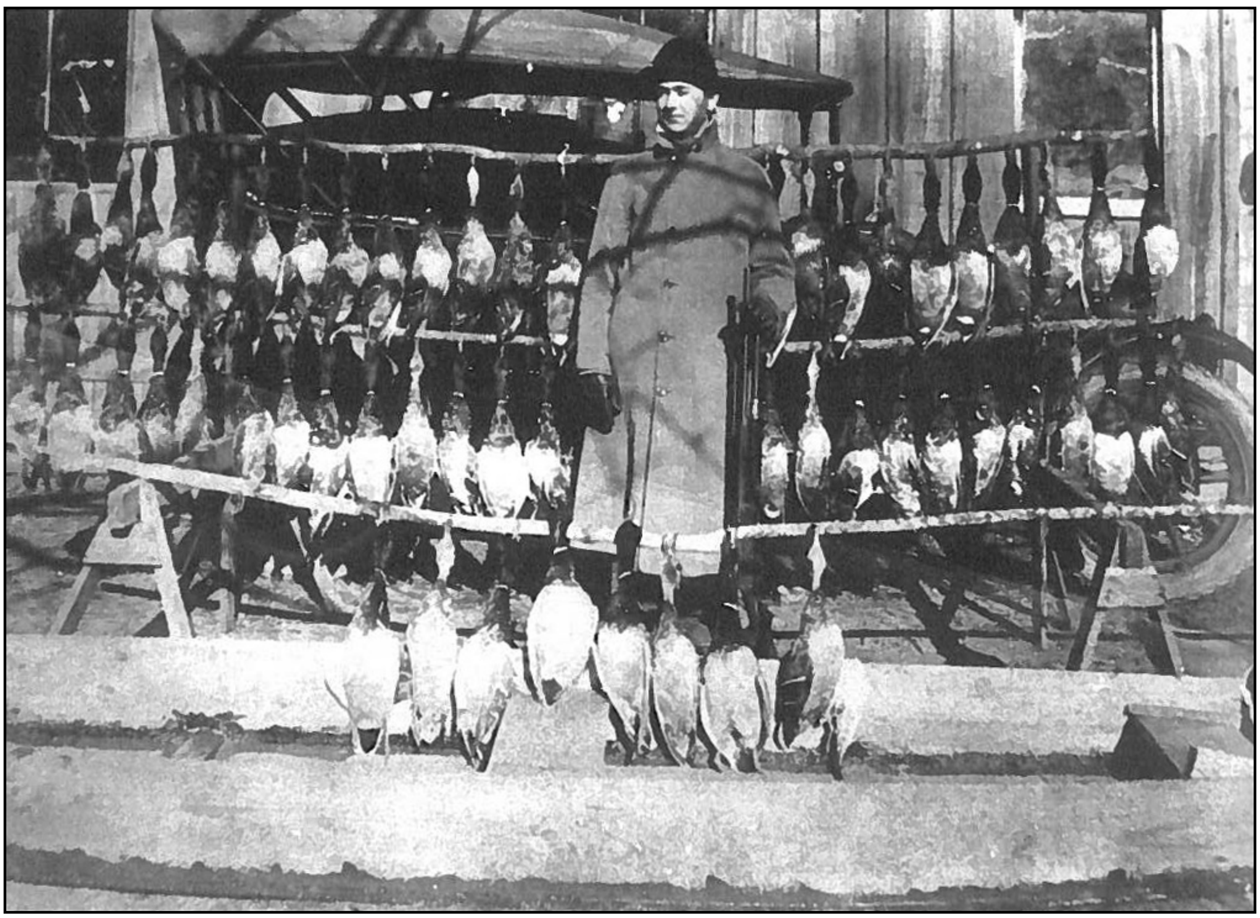

Figure 7. Waterfowl hunter at Grassy Lake in 1914.

In 2004, Congress directed the Little Rock District, USACE, to initiate an Ecosystem Restoration Feasibility Study of the Grassy Lake area under Section 1135 of the Water Resources Development Act. Subsequent investigations verified that the water control projects in the Little River drainage basin had adversely affected the entire Lower Little River Bottoms ecosystem, including Grassy Lake. The U.S. Army Engineer Research and Development Center (ERDC) was enlisted by the District to work with the state and local stakeholders to devise an ecosystem restoration plan for the region. An essential part of this restoration plan was to identify the historical, pre-dam conditions of the study area. Characterizing the pre-dam environment involved investigations of three major ecosystem components: hydrology, geomorphology, and the distribution of native plant communities. The GLO plat maps and survey notes for the study area provided information about the historical condition for all three of these ecosystem components.

**METHODS:** Prior to the initiation of this study, the Arkansas State Land Surveyor's Office had transcribed the original handwritten GLO survey notes for the entire state, indexed them, and made them available as digital files (Daniels 2000). The GLO surveys for the study area were undertaken from 1819 through 1842, with the surveys of Grassy Lake occurring in 1834. For this study, the transcribed GLO survey notes for the study area were entered into an Excel spreadsheet, including the entire townships of T12S R27W and T13S R27W and portions of the adjacent townships. Most landscape features and their locations were entered on a separate line in the spreadsheet, and each tree description was given its own line. However, the hydrologic features and general landscape descriptions often were combined with the tree data when they occurred at the same location. Each line in the spreadsheet was given a unique identifier and the distance at which the features occurred along the survey line was recorded in the "distance" column. Other location information, such as the township and range, the section number, the side of the section (e.g. south or east), and the direction the surveyor walked, were recorded in the spreadsheet. Tree species, tree diameter in inches, and the direction and distance to bearing trees were included. The type and name of hydrologic features, such as lakes and rivers, feature width, and bearing were recorded in the spreadsheet. All other non-numerical survey information, including general descriptions of the landscape and land ownership, was recorded within the spreadsheet as comments associated with particular survey points.

A raster image showing the section boundary lines for the region was obtained from GeoStor (GeoStor 6.0 2009). This layer, created by the USGS, is a digital depiction derived from USGS 1:100,000-scale 30- by 60-minute quadrangle maps. This raster layer was then added into an ArcMap 9.3 (ESRI 2008) map document. Using this layer as a reference, points were digitized at the section corners and saved as a vector shapefile. The UTM coordinates of these section corners were determined using ArcMap. Since the surveyors measured along the section lines from the section corners, the landscape features in the survey notes can be located in GIS by relating them to those section corners. The UTM coordinates for the corner section from which each landscape feature was measured were also entered into the Excel spreadsheet, creating "X_origin" and "Y_origin" columns. The bearing from the section corners was also needed to digitize the survey notes. The surveyors recorded the cardinal direction in which they walked; the exact bearing for these were then determined using the grid layer to be: North = 2.2, South = 182.1, West = 272.3, and East = 92.3. These were then included as a "bearings" column in the spreadsheet.

Once the survey notes were entered into the spreadsheet, they were transferred to a GIS shapefile using two extensions, Distance/Azimuth Tools, v. 1.6 (Jenness 2005) and Script/Dialog Tools, v. 2.0016 (Jenness 2007), in ArcView 3.3 (ESRI 2002). First the Excel spreadsheet was converted into a dBASE table using the Script/Dialog Tools extension. This table was then converted to an event theme, using the "X_origin" and "Y_origin" columns as the "X field" and "Y field." The

Distance/Azimuth Tools extension was then used to create a point shapefile from the table containing the survey notes. This extension provides a variety of methods for creating shapefiles; for this project the method used was the "INPUT THEME, using unique distances and azimuths." The event theme created above was used as the "Input Theme," the "distance" column was used as the "Distance field," and the "bearing" column was used as the "Azimuth field." (Note: the above steps also can be accomplished in current versions of ArcGIS using the Survey Analyst software extension). All of the attribute fields from the spreadsheet were transferred to the new point shapefile, which was added as a layer into ArcMap, along with the digital versions of the plat maps for the townships. Once the survey notes and plat maps were georeferenced in ArcMap, the surveyors' observations could be analyzed and compared with current conditions in the study area.

The GLO descriptions and data were used to reconstruct pre-settlement conditions, including mapping the vegetation and the positions of streams, characterizing flooding conditions, and contributing key data to the detailed hydrologic modeling of the pre-dam landscape. These analyses were used to identify the fundamental changes that had occurred in ecosystem structure and processes. They were also used to determine the extent to which those changes are reversible, and if not, what alternative conditions can be established and maintained. The resulting ecosystem restoration plan (Klimas et al. 2010) includes specific recommendations for forest management, reforestation, stream restoration, and an experimental approach for developing a dynamic water management plan that will sustain the Lower Little River Bottoms and Grassy Lake ecosystem.

**RESULTS AND DISCUSSION:** The GLO surveyors reported few signs of human activity within the wilderness of the Lower Little River Bottoms. Like most of southwestern Arkansas, the area was only sparsely settled when the GLO survey was conducted, and no large-scale land clearing or other extensive human alterations had taken place. Therefore, the conditions reported in the survey notes represent a reasonable approximation of the undisturbed (pre-settlement) reference condition for the ecosystem.

The GLO survey observations form a grid across the study area, providing information at regular intervals concerning line trees, bearing trees, water features, and the surveyors' general descriptions of the landscape (Figure 8). The survey data and plat maps identified the historical positions of streams and rivers; comparing these to the current locations confirmed that most had not been modified and only minor natural shifts in channel position had occurred. However, the survey data verified that one major stream had been straightened and rerouted to significantly alter its interaction with Grassy Lake, causing accelerated sedimentation of the lake. Based on that analysis, restoration of the original stream channel became a major component of the final ecosystem restoration plan for the area. The GLO data also provided details about the native plant communities observed by the surveyors, allowing specific comparisons with the modern vegetation distribution pattern. Much of the bottomlands show little or no change in tree species composition since the early 1800s, but in the uplands, GLO surveyors noted expanses of prairie and open woodlands, indicating fire was a more common influence than it is currently. Based on this information, prescribed fire in the uplands is a recommended component of the ecosystem restoration plan.

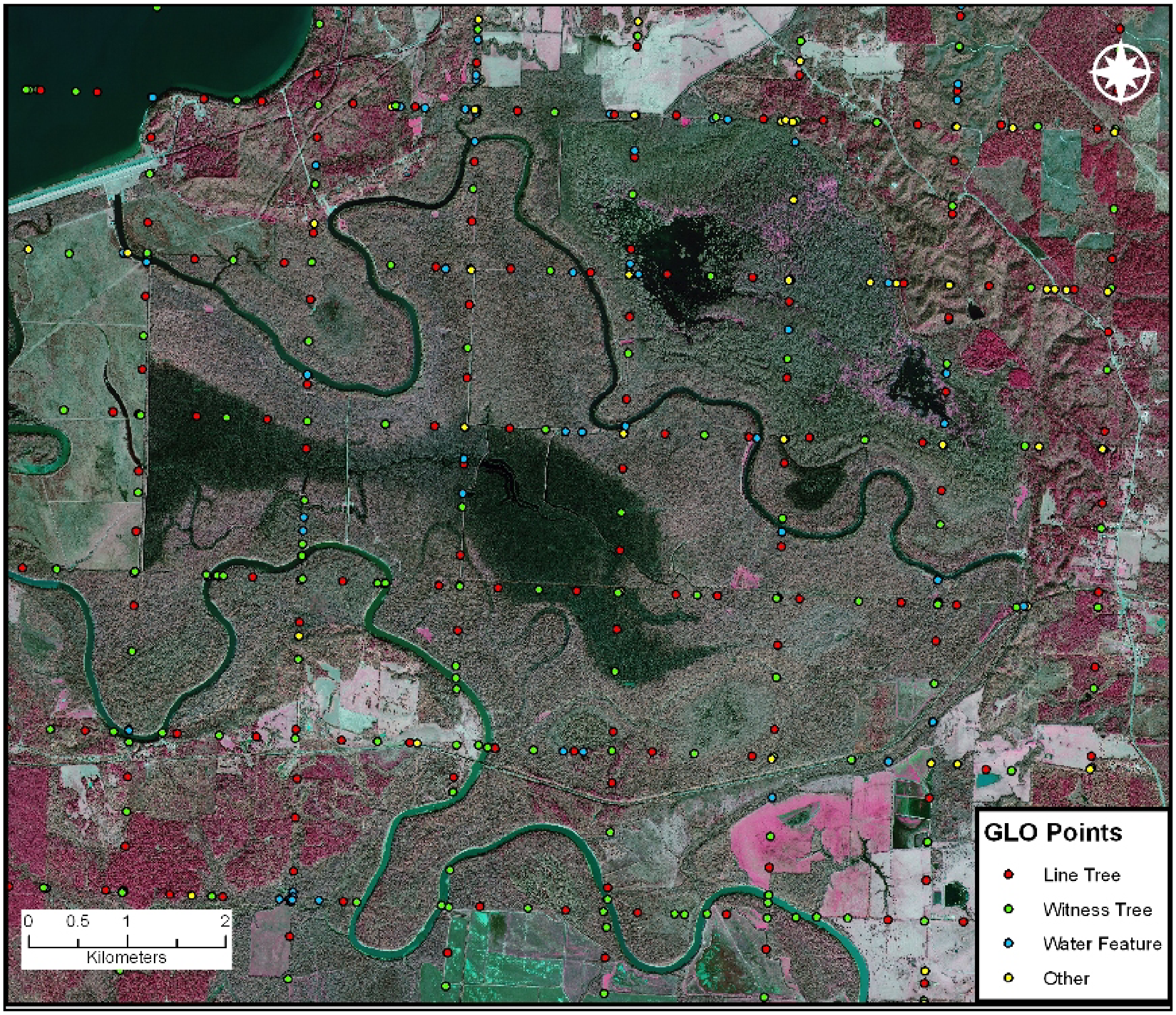


Figure 8. The distribution of observations made by the GLO surveyors, superimposed on a recent image of the Lower Little River Bottoms.

The narrative descriptions of land condition and flood depths that appear in the GLO survey records were useful in reconstructing the pre-dam hydrology of the study area. For example, the surveyors recorded the following concerning part of one survey line within Grassy Lake:

> "Land in Lake covered with water from 1 to 4 feet deep and in places very miry, some locust, cypress in spots. Undergrowth saw grass and button bushes."

Descriptions such as these verified historical flooding of the bottomlands and provided a snapshot of conditions within Grassy Lake. However, a full characterization of inundation depths and durations based on hydrologic modeling was needed to guide the ecosystem restoration water management plan. This was accomplished for most of the bottomlands using pre-dam flow records for the Little River, but for Grassy Lake itself, additional data were needed.

Grassy Lake differs from the rest of the Little River lowlands in that it is actually a cypress swamp in a topographic basin, rather than a floodplain hardwood forest. The hydrology of the Grassy Lake basin is driven more by runoff from a local tributary, Yellow Creek (see Figure 6), and evapotranspiration than by overbank flows from the Little River. Under pre-development conditions, Grassy Lake would have had much of its substrate exposed for extended periods and at regular intervals. This is essential for cypress reproduction, though enough permanent water was present in deeper areas for the GLO surveyors to refer to the entire swamp as a lake. The levees and water control structures that were built in the mid-20th century were used to deepen, expand, and maintain the permanent pool sufficiently to support game fish populations and to allow flooding of the adjacent hardwood forests to attract waterfowl during hunting season. The objective of the hydrologic modeling process for Grassy Lake was to develop a water management plan that emulates the natural patterns of water fluctuation that once sustained the cypress swamp. However, the hydrologic modeling process lacked a key piece of information - the original "full pool" level and storage volume of the lake prior to the extensive construction of levees and drainage structures, which had obliterated evidence of the elevation of the original lake outlet. The GLO data were used to supply that critical information.

Although the GLO surveyors sometimes surveyed the entire perimeter of a body of water, they did not do so for Grassy Lake. The lakeshore depicted on the plat map (Figure 5) is an approximation based on extrapolation between actual survey points. By using the original survey points in conjunction with modern topographic information in GIS, a much more accurate approximation of the original shoreline was created. The reconstructed shoreline nonetheless reflects only the water level that was present in the lake at the time the surveyors conducted their field work; it cannot be assumed to represent the full pool level or any other benchmark that can be used to recommend future water level management designed to re-establish the hydrologic patterns that sustained the original ecosystem. Therefore, the GLO tree data were closely examined to determine whether the shoreline contour calculated from the original GLO data represented the natural full pool condition for the swamp, or whether the contour should be adjusted either upward or downward. Figure 9 compares the current contour elevation of Grassy Lake at full pool and the lower, original shoreline contour as calculated from the GLO survey data, and illustrates the positions and species of trees observed at each of the original survey points within the modern lake boundary. Table 1 summarizes the distribution of those tree species between the modern full-pool lake perimeter and estimated original (or historical) lake level, and below the historical pool level.

All of the trees observed by the surveyors within the historical lake boundary were species normally found in cypress swamps. They include cypress, which tolerates extended periods of flooding, as well as locust (presumably water locust), willow, buttonbush, and ash (presumably green ash); all can survive extended inundation for some time once they are established. However, all of these species require exposed substrates to germinate, and all but cypress and buttonbush require an extended dry period following germination to establish well enough to persist through subsequent floods. Regardless of whether these less-tolerant species are able to establish, they typically will not survive years where flooding remains through the growing season. This happens often enough in cypress swamps to maintain dominance by cypress and/or tupelo. The relative sizes of the trees listed in Table 1 tend to verify that species other than

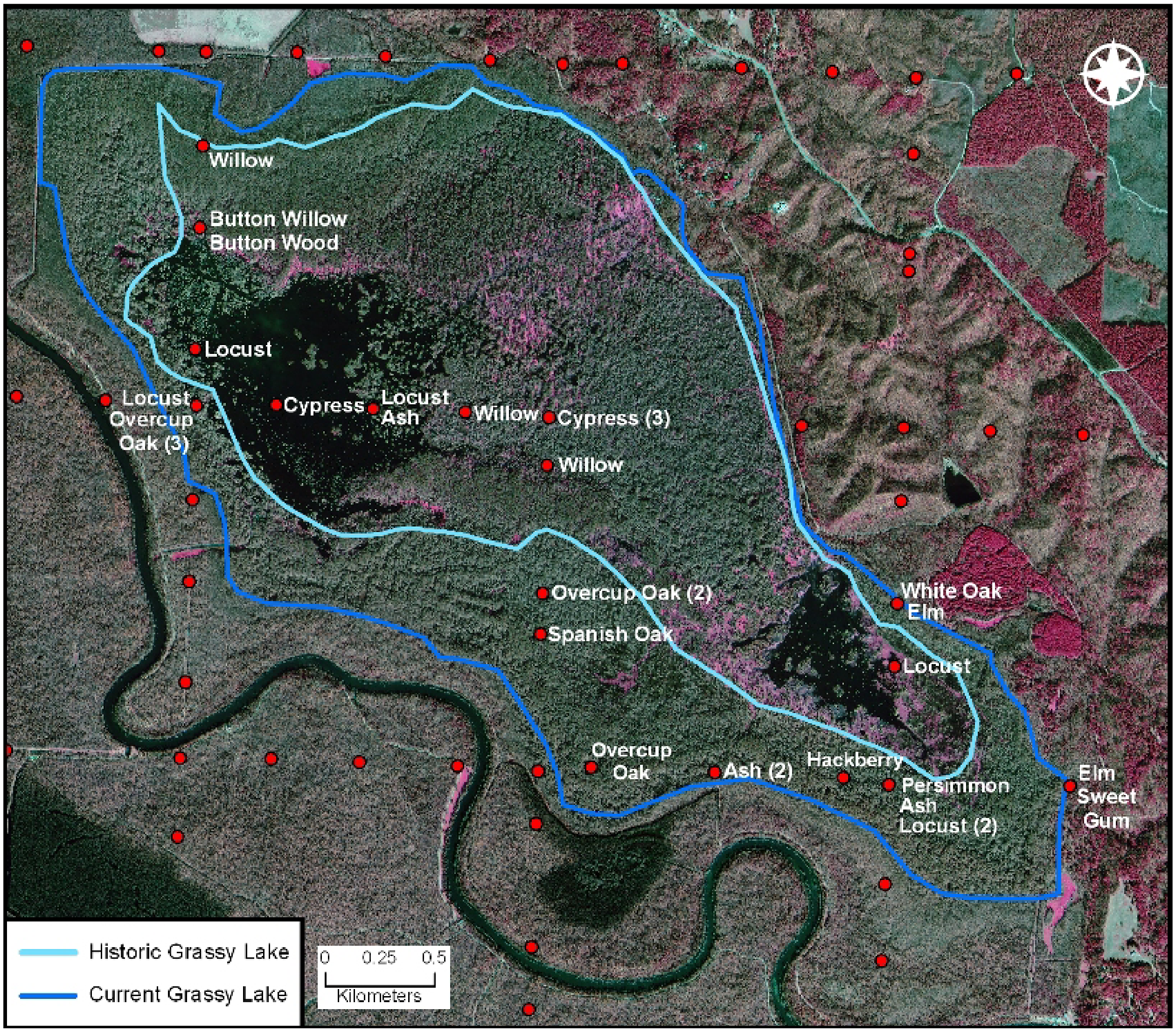


Figure 9. Approximate current and historical full pool perimeters of Grassy Lake showing the positions of individual trees observed by the GLO surveyors.

cypress and buttonbush are not long-term components of the swamp forest. All of the large-diameter trees within the pool at the time of the survey were bald cypress, including individuals that could have been present for a century or more; all other tree species were relatively small, indicating they had been present for only a decade or two at most. Conversely, the trees in the zone above the historical pool level were primarily species tolerant of normal seasonal river flooding — overcup oak, hackberry, persimmon — which occurred in the area prior to dam construction, but are not able to survive the long-term inundation typical of a cypress swamp. The sizes of those trees (Table 1) indicate that some also had been present for a century or more; therefore, seasonal flooding had been the prevailing pattern for at least that long. Today, none of those species are present within the current lake full pool perimeter — instead, cypress and willow occupy that zone.

**Table 1. Species and diameters of trees identified in Figure 9 as recorded by the GLO surveyors.**

| Current Lake Boundary | | Historic Lake Boundary | |
|---|---|---|---|
| **Tree Species** | **Diameter (in.)** | **Tree Species** | **Diameter (in.)** |
| Locust | 12 | Willow | 10 |
| Overcup Oak | 28 | Button Willow | 5 |
| Overcup Oak | 12 | Button Wood | 4 |
| Overcup Oak | 13 | Locust | 8 |
| Overcup Oak | 14 | Cypress | 24 |
| Overcup Oak | 13 | Locust | 7 |
| Spanish Oak | 16 | Ash | 8 |
| Overcup Oak | 16 | Willow | 10 |
| Ash | 9 | Cypress | 18 |
| Ash | 5 | Cypress | 16 |
| Hackberry | 8 | Cypress | 17 |
| Persimmon | 8 | Willow | 8 |
| Ash | 10 | Locust | 12 |
| Locust | 8 | | |
| Locust | 12 | | |
| Sweet Gum | 24 | | |
| Elm | 10 | | |
| White Oak | 24 | | |
| Elm | 7 | | |

This analysis verified that the estimated historical lake contour does in fact represent the natural full-pool elevation of Grassy Lake. It also confirmed that the hydrologic patterns commonly seen in cypress swamps likely also occurred in Grassy Lake–generally shallow water conditions, but with regular substrate exposure during dry periods, sometimes extending for multiple years, allowing regeneration of the cypress forest as well as establishment of other, less water-tolerant, species. Just as there were extended dry periods, there were times when flooding continued throughout the growing season and for multiple years, sufficient to kill the less tolerant species. The ecosystem restoration plan derived from these observations stipulates a much more dynamic water fluctuation pattern than the one that has been employed since the lake level was raised in the mid-20th century. Regular substrate exposure will be required to maintain cypress regeneration and vigor. Drawdowns are currently avoided, in part to help sustain fisheries and to ensure water availability during waterfowl season; therefore, the restoration plan includes hydrologic modifications to restore some of the historical stream flows and provide other water sources into the lake so that managers can manipulate water levels and emulate natural fluctuation patterns as needed, without losing traditional waterfowl habitat. The artificial fish habitat that was created by converting the swamp to a true lake likely will not be compatible with ecosystem restoration goals.

GLO survey data can be used for more detailed vegetation analyses than were needed at Grassy Lake (Bourdo 1956, Brothers 1991). In many instances, ecosystem restoration requires reforestation of large tracts of land that have been converted to agriculture, and the GLO tree data can be used to determine the appropriate species composition for various restoration sites. The bearing tree data include species, diameter, distance from the survey line, and direction from the line. These are the same data collected in point-quarter sampling, a standard method in forest ecology (Cottam and Curtis 1956). By using this approach and linking the summarized forest community descriptions to their associated site data (such as soils, flood frequency, and geomorphology) the GLO data can provide a template for reforestation over large areas. This method also can be used to detect major changes that have occurred within existing forests due to timber harvest, fire exclusion, flood control, and other influences. Tingle et al. (2001) provide an example of this type of application for a portion of the Mississippi Alluvial Valley in eastern Arkansas.

**CONCLUSIONS:** GLO survey notes and plat maps are an important information source for establishing the historical reference condition that can be used in ecosystem restoration. GLO surveys were conducted in 30 states: Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, South Dakota, Utah, Washington, Wisconsin, and Wyoming. Information about General Land Office surveys, as well as many of the survey notes and plat maps can be obtained from the Bureau of Land Management *http://www.glorecords.blm.gov/*. This website does not have all of the survey notes available, and most of the available notes are scanned copies of the original handwritten notes. However, many of the handwritten notes were transcribed (typed) in the 20th century, making them easier to interpret. Another resource for the survey notes and plat maps are state land offices. Some states also have the survey notes available online. In searching for information about the General Land Office surveys, it is important to note that these surveys are also often referred to as the Public Land Survey System (PLSS).

**ACKNOWLEDGEMENTS:** Jeff Jenness of Jenness Enterprises was instrumental in converting the GLO survey notes to a GIS shapefile, and provided the two ArcView extensions used for this project. More information about Jenness Enterprises and these extensions can be found at *http://www.jennessent.com/*.

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**ADDITIONAL INFORMATION:** The analysis described in this publication was conducted as part of the Ecosystem Restoration Feasibility Study for the Grassy Lake area of southwestern Arkansas, authorized by Congress in 2004 under Section 1135 of the Water Resources Development Act. Julia Smethhurst, Little Rock District, Corps of Engineers, was Project Manager. This technical note was prepared as an activity of the Ecosystem Management and Restoration Research Program (EMRRP). For information on EMRRP, please consult *http://el.erdc.usace.army.mil/emrrp/emrrp.html* or contact the Program Manager, Glenn Rhett, at *Glenn.G.Rhett@usace.army.mil*.

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